General Methodology for Designing Spacecraft Trajectories

Lyndon B. Johnson Space Center, Houston, Texas

A methodology for designing spacecraft trajectories in any gravitational environment within the solar system has been developed. The methodology facilitates modeling and optimization for problems ranging from that of a single spacecraft orbiting a single celestial body to that of a mission involving multiple spacecraft and multiple propulsion systems operating in gravitational fields of multiple celestial bodies. The methodology consolidates almost all spacecraft trajectory design and optimization problems into a single conceptual framework requiring solution of either a system of nonlinear equations or a parameter-optimization problem with equality and/or inequality constraints.

The use of multiple reference frames that generally translate, rotate, and pulsate between two arbitrary celestial bodies facilitates analysis of such complex trajectories as those that pass (possibly multiple times) through gravitational fields of multiple celestial bodies. A basic building block that can accommodate impulsive maneuvers, maneuver- and non-maneuver-based mass discontinuities, and finite burn or finite control acceleration maneuvers, is used to construct trajectories. The methodology is implemented in an interactive computer program, COPERNICUS, wherein numerical integration, multi-dimensional nonlinear root-finding, and/or sequential quadratic programming are used for solving trajectory design, targeting, or optimization problems constructed by the analyst.

This work was done by Gerald Condon of Johnson Space Center; Cesar Ocampo, Ravishankar Mathur, and Fady Morcos of the University of Texas; Juan Senent of Odyssey Space Research; Jacob Williams of ERC, Inc.; and Elizabeth C. Davis of Jacobs Technology. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-23671-1/4209-1/4586-1

High-Thermal-Conductivity Fabrics

Applications include cooling garments for firefighters, hazmat personnel, soldiers, and in cooling vests for multiple sclerosis patients.

Lyndon B. Johnson Space Center, Houston, Texas

Heat management with common textiles such as nylon and spandex is hindered by the poor thermal conductivity from the skin surface to cooling surfaces. This innovation showed marked improvement in thermal conductivity of the individual fibers and tubing, as well as components assembled from them.

The problem is centered on improving the heat removal of the liquid-cooled ventilation garments (LCVGs) used by astronauts. The current design uses an extensive network of water-cooling tubes that introduces bulkiness and discomfort, and increases fatigue. Range of motion and ease of movement are affected as well. The current technology is the same as developed during the Apollo program of the 1960s. Tubing material is hand-threaded through a spandex/nylon mesh layer, in a series of loops throughout the torso and limbs such that there is close, form-fitting contact with the user. Usually, there is a nylon liner layer to improve comfort. Circulating water is chilled by an external heat exchanger (sublimator).

The purpose of this innovation is to produce new LCVG components with improved thermal conductivity. This was addressed using nanocomposite engineering incorporating high-thermal-conductivity nanoscale fillers in the fabric and tubing components. Specifically, carbon nanotubes were added using normal processing methods such as thermoplastic melt mixing (compounding twin screw extruder) and downstream processing (fiber spinning, tubing extrusion). Fibers were produced as yarns and woven into fabric cloths. The application of isotropic nanofillers can be modeled using a modified Nielsen Model for conductive fillers in a matrix based on Einstein's viscosity model.

This is a drop-in technology with no additional equipment needed. The loading is limited by the ability to maintain adequate dispersion. Undispersed materials will plug filtering screens in processing equipment. Generally, the viscosity increases were acceptable, and allowed the filled polymers to still be processed.

The novel feature is that fabrics do not inherently possess good thermal conductivity. In fact, fabrics are used for thermal insulation, not heat removal. The technology represents the first material that is a wearable fabric, based on company textiles and materials that will significantly conduct heat.

This work was done by L. P. Felipe Chibante of NanoTex Corporation for Johnson Space Center. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Materials & Coatings category.***

NanoTex Corporation
9402 Alberene Dr.
Houston, TX 77074

Refer to MSC-24389-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Saliva Preservative for Diagnostic Purposes

This preservative can be used in remote areas without refrigeration for at least two months.

Lyndon B. Johnson Space Center, Houston, Texas

Saliva is an important body fluid for diagnostic purposes. Glycoproteins, glucose, steroids, DNA, and other molecules of diagnostic value are found in saliva. It is easier to collect as compared to blood or urine. Unfortunately, saliva also contains large numbers of bacteria that can release enzymes, which can degrade proteins and nucleic acids. These degradative enzymes destroy or reduce saliva's diagnostic value. This innovation describes the formulation of a chemical preservative that prevents microbial growth and inactivates the degradative enzymes. This extends the time that saliva can be stored or transported without losing its diagnostic value. Multiple samples of saliva can be collected if needed without causing discomfort to the subject and it does not require any special facilities to handle after it is collected.

The preservative contains sodium dodecyl sulfate (SDS), ethylenediaminetetraacetic acid (EDTA), and Tris buffer. This preservative was developed to preserve saliva from astronauts during spaceflight without refrigeration to determine if virus DNA was present. Saliva with added preservative can be stored at room temperature for up to 60 days without any measureable degradation. Viral DNA is routinely measured from saliva stored in this manner without refrigeration. Thus, this preservative can be used to preserve critical macromolecules (nucleic acids and proteins) without consuming power resources. This preservative has been used on flight experiments aboard both the Space Shuttle and the International Space Station.

Saliva contains hormones such as cortisol and DHEA, cytokines (immune markers), DNA and RNA viruses, antibodies, and many other substances of diagnostic value. Saliva also contains many bacteria that produce proteases that destroy proteins, nucleases that destroy DNA and RNA, and other degradative enzymes. Typically, saliva and other body fluids are refrigerated (or frozen) to prevent or slow the degradation process. Refrigeration and freezers are extremely limited resources in spacecraft, undeveloped countries, and during activities away from electricity. Although not tested, the preservative is expected to be effective for other body fluids such as urine and blood. In addition, the toxicity of the preservative is very low.

The preservative consists of 0.5% sodium dodecysulfate (a detergent), 1.0 mM EDTA (a metal chelator), and 1.0 mM Tris (a buffer to maintain correct pH). The preservative is stable at room temperature for at least six months. A small volume of the liquid preservative is added to saliva (or other body fluids), the mixture is mixed by inversion, and then is left undisturbed at room temperature until the analysis is conducted. No other preservative has been identified that stabilizes saliva and other body fluids at room temperature for subsequent analyses.

This work was done by Duane L. Pierson of Johnson Space Center and Satish K. Mehta of EASI. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Bio-Medical category****.* *MSC-25144-1*

Ultra-Compact Motor Controller

Applications include industrial robotic arms, industrial machinery, and automobiles.

Lyndon B. Johnson Space Center, Houston, Texas

This invention is an electronically commutated brushless motor controller that incorporates Hall-array sensing in a small, 42-gram package that provides 4096 absolute counts per motor revolution position sensing. The unit is the size of a miniature hockey puck, and is a 44-pin male connector that provides many I/O channels, including CANbus, RS-232 communications, general-purpose analog and digital I/O (GPIO), analog and digital Hall inputs, DC power input (18–90 VDC, 0–10 A), three-phase motor outputs, and a strain gauge amplifier.

This controller replaces air cooling with conduction cooling via a high-thermal-conductivity epoxy casting. A secondary advantage of the relatively good heat conductivity that comes with ultra-small size is that temperature differences within the controller become smaller, so that it is easier to measure the hottest temperature in the controller with fewer temperature sensors, or even one temperature sensor.

Another size-sensitive design feature is in the approach to electrical noise immunity. At a very small size, where conduction paths are much shorter than in conventional designs, the ground becomes essentially isopotential, and so certain (space-consuming) electrical noise control components become unnecessary, which helps make small size possible. One winding-current sensor, applied to all of the windings in fast sequence, is smaller and wastes less power than the two or more sensors conventionally used to sense and control winding currents. An unexpected benefit of using only one current sensor is that it actually improves the precision of current control by using the "same" sensors to read each of the three phases. Folding the encoder directly into the controller electronics eliminates a great deal of redundant electronics, packaging, connectors, and hook-up wiring. The reduction of wires and connectors subtracts substantial bulk and eliminates their role in behaving as EMI (electromagnetic interference) antennas.

A shared knowledge by each motor controller of the state of all the motors in the system at 500 Hz also allows parallel processing of higher-level kinematic matrix calculations.

This work was done by William T. Townsend, Adam Crowell, and Traveler Hauptman of Barrett Technology, Inc., and Gill Andrews Pratt of Olin College for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Barrett Technology, Inc.
625 Mount Auburn Street
Cambridge, MA 02138-4555
Phone No.: (617) 252-9000
Web site: www.barrett.com

Refer to MSC-23930-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Hands-Free Transcranial Color Doppler Probe

These probes enable full use of TCD technology for neurological diagnostics.

Lyndon B. Johnson Space Center, Houston, TX

Current transcranial color Doppler (TCD) transducer probes are bulky and difficult to move in tiny increments to search and optimize TCD signals. This invention provides miniature motions of a TCD transducer probe to optimize TCD signals.

The mechanical probe uses spherical bearing in guiding and locating the tilting crystal face. The lateral motion of the crystal face as it tilts across the full range of motion was achieved by minimizing the distance between the pivot location and the crystal face. The smallest commonly available metal spherical bearing was used with an outer diameter of 12 mm, a 3-mm tall retaining ring, and 5-mm overall height. Small geared motors were used that would provide sufficient power in a very compact package. After confirming the validity of the basic positioning concept, optimization design loops were completed to yield the final design.

A parallel motor configuration was used to minimize the amount of space wasted inside the probe case while minimizing the overall case dimensions. The distance from the front edge of the crystal to the edge of the case was also minimized to allow positioning of the probe very close to the ear on the temporal lobe. The mechanical probe is able to achieve a ±20° tip and tilt with smooth repeatable action in a very compact package. The enclosed probe is about 7 cm long, 4 cm wide, and 1.8 cm tall.

The device is compact, hands-free, and can be adjusted via an innovative touchscreen. Positioning of the probe to the head is performed via conventional transducer gels and pillows. This device is amendable to having advanced software, which could intelligently focus and optimize the TCD signal.

The first effort will be development of monitoring systems for space use and field deployment. The need for long-lived, inexpensive clinical diagnostic instruments for military applications is substantial. Potential future uses of this system by NASA and other commercial end-users include monitoring cerebral blood flow of ambulatory patients, prognostic of potential for embolic stroke, ultrasonic blood clot treatment, monitoring open-heart and carotid endarterectomy surgery, and resolution of the controversy regarding transient ischemic attacks and emboli's role. Monitoring applications include those for embolism formation during diving ascents, changes in CBFV (cerebral blood flow velocity) in relation to cognitive function as associated with sick building syndrome or exposure to environmental and workplace toxins, changes of CBFV for testing and evaluating Gulf War Syndrome, and patients or subjects while moving or performing tasks.

This work was done by Robert Chin of GeneXpress Informatics, and Srihdar Madala and Graham Sattler of Indus Instruments for Johnson Space Center. ***For more information, download the Technical Support Package (free white paper) at www.medicaldesignbriefs.com.***

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Indus Instruments
721 Tristar Drive, Suite C
Webster, TX 77598

Refer to MSC-24702-1, volume and number of this Medical Design Briefs *issue, and the page number.*